Improving the stratocumulus simulation in the GFS: Report

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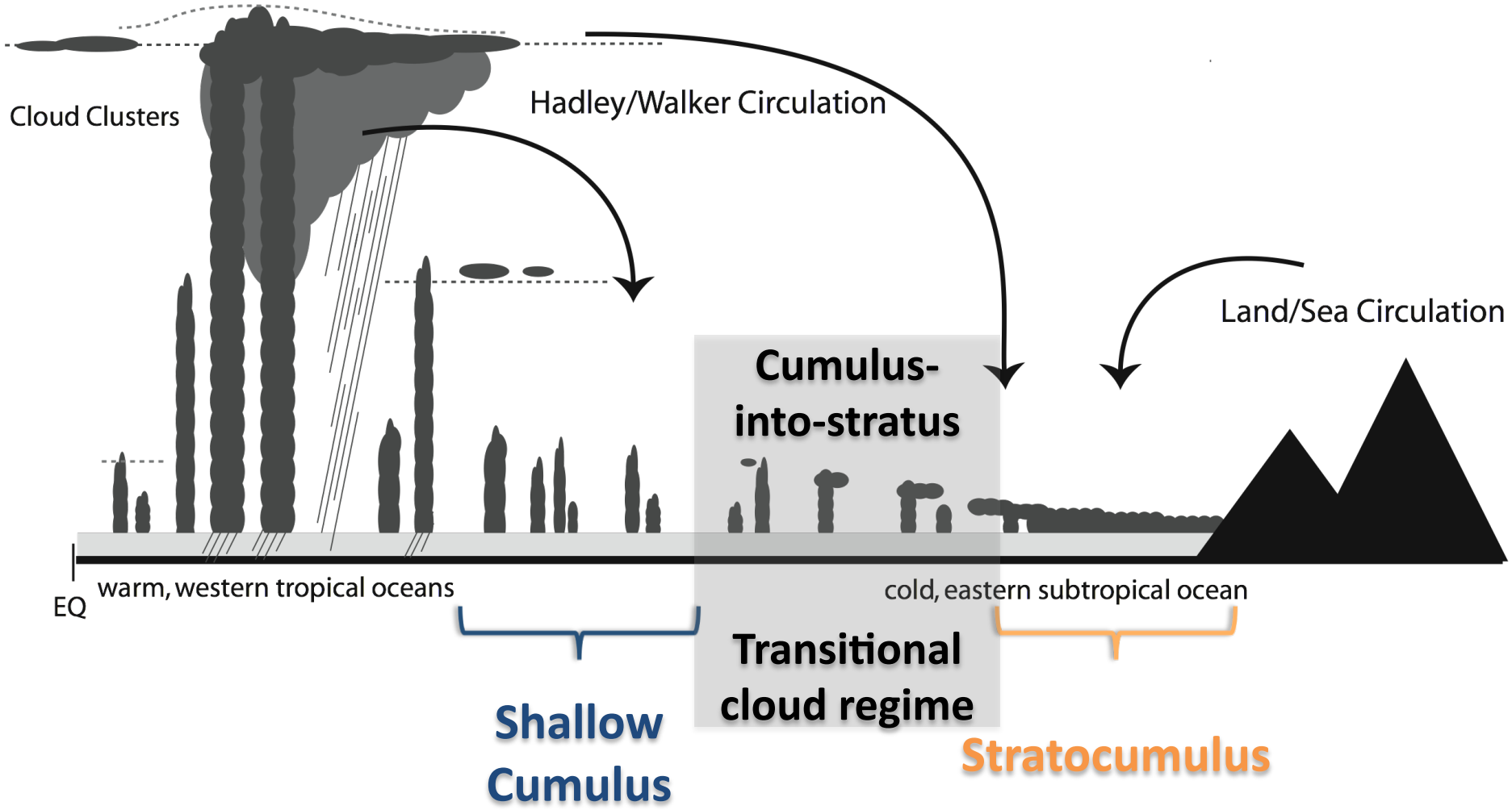
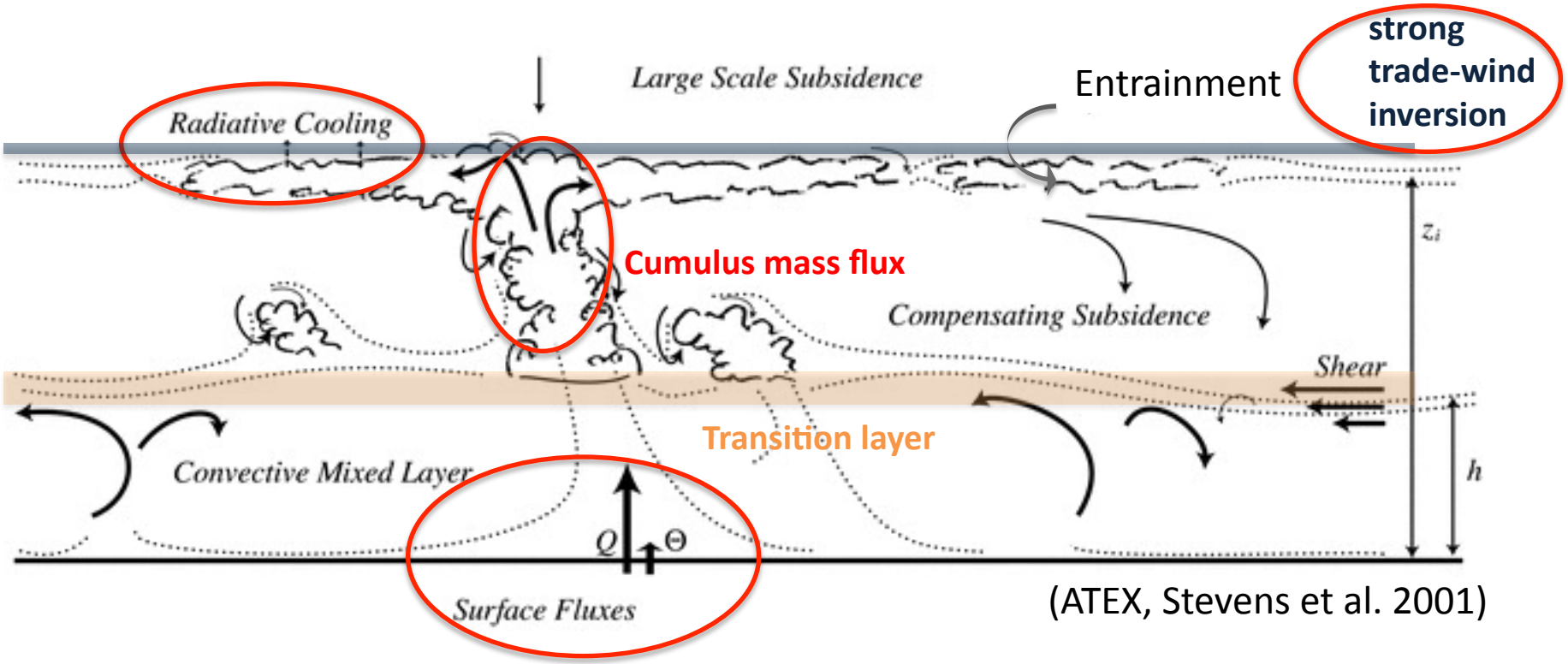
Schematic for Low Cloud Regimes over Subtropical Oceans



Detailed studies of the stratocumulus-shallow cumulus transition (e.g., Wyant et al. 1997) highlight the importance of a transitional, or cumulus-into-stratus regime.

The transitional cloud regime



(ATEX, Stevens et al. 2001)

We need to take into account "controls" from both the top and the bottom in shallow cumulus and PBL parameterizations, like those in the efforts of Bretherton et al. and here at NCEP.

We have been attempting to represent such "controls" in the GFS context on the basis of two concepts: CTEI and Decoupling.

CTEI or buoyancy reversal occurs at the inversion when:

$$\kappa = \frac{c_p \Delta\theta_e}{L\Delta q_t} = 1 + \frac{c_p \Delta\theta_l}{L\Delta q_t} > \kappa_0$$

(Δ means the jump across the inversion. See Randall (1980), Deardorff (1980, 1984) and Siems et al. (1990); It has been suggested that κ_0 is about 0.7)

Decoupling can occur in the cloud-topped PBLs. **The degree of decoupling** has been expressed as:

$$D\,(or\ BIR) = -\int_{z<z_i^-,\ \overline{w'b'}<0} \overline{w'b'}\,dz \Big/ \int_{\overline{w'b'}\geq 0} \overline{w'b'}\,dz$$

(Bretherton and Wyant (1997); It has been suggested that if D is larger than 0.15, then the mixed layer assumption breaks down.)

A LES-based study

Hypothesis Tested

	Decoupled SMBL (large D)	Well-mixed SMBL (small D)
Large κ	(A) Stratocumulus is destroyed, and the transition is highly probable.	(B) Stratocumulus is reduced, but the transition is highly unlikely
Small κ	(C) Stratocumulus and the "controls" from the cloud-top on the underlying cumulus cloud layer is still significant. **(*)**	(D) No transition occurs.

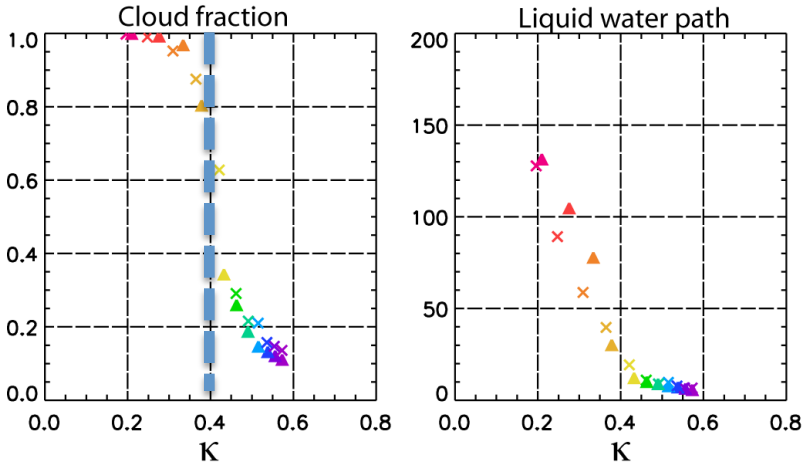
Table 1: Possible SMBL scenarios for the transition from a SMBL to a TCMBL.

(*) It is probable that cases in this category will transit to shallow cumulus eventually due to "cloud-top entrainment" induced drying (Wyant et al. 1997).

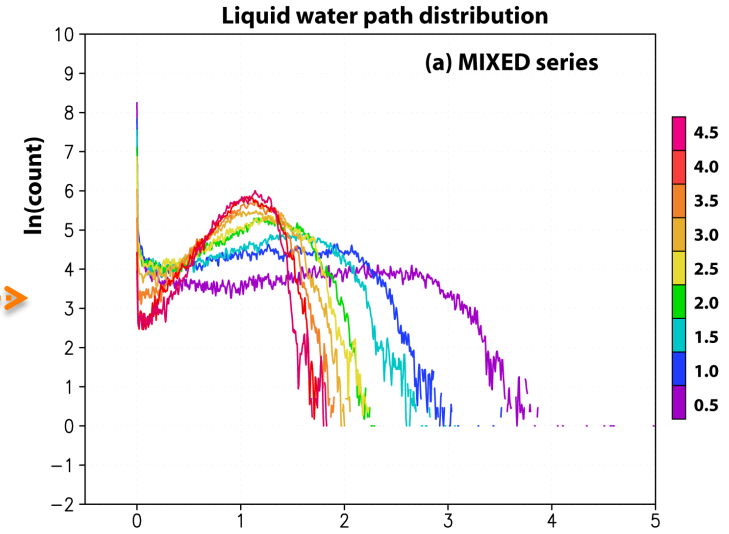
This study suggests that $\kappa_0 \sim 0.4$

From Xiao et al. (2010)

Kappa .vs. clouds in DECOUPLED case



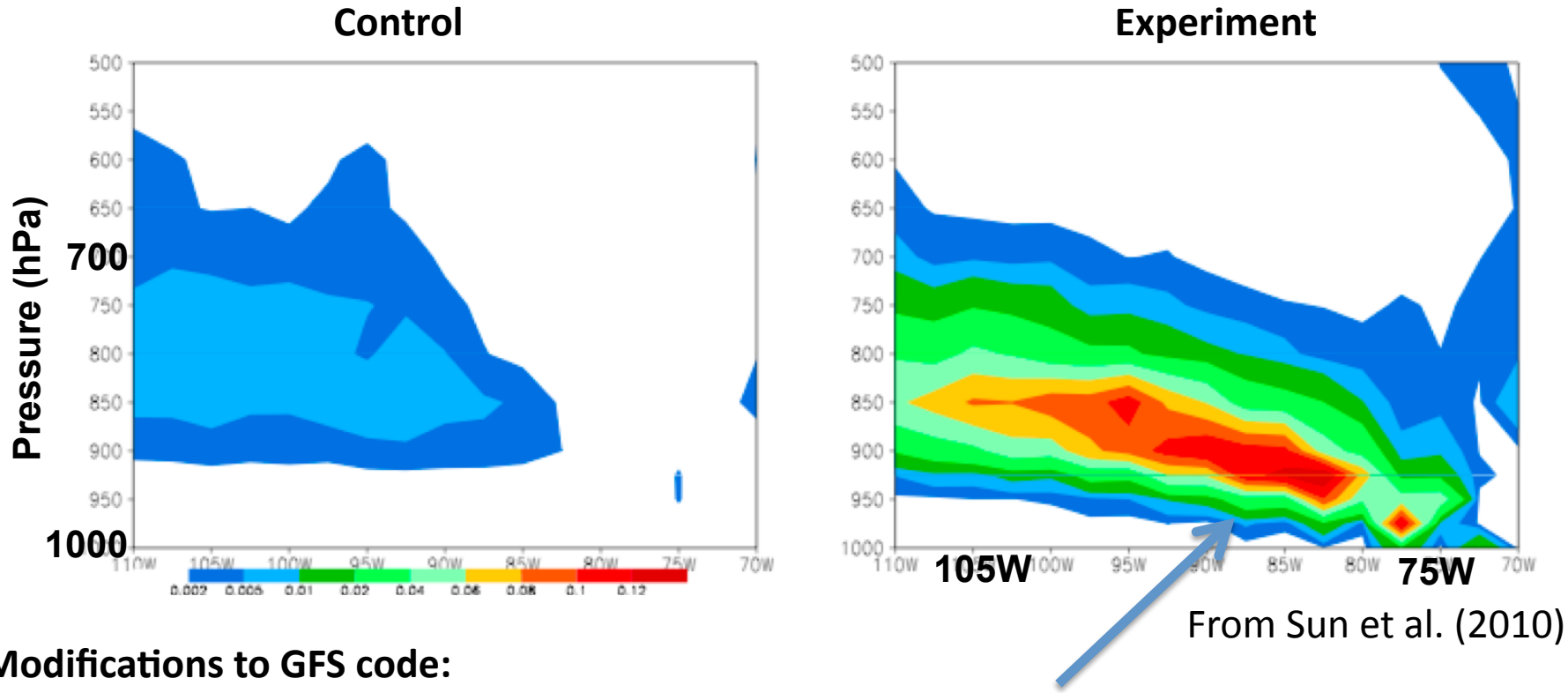
Kappa .vs. LWP p.d.f. in MIXED case



Large kappa makes stratus patchy while a stratus layer persists on.

Application to NCEP GFS

Vertical cross section of cloud water mixing ratio along 20°S for July



From Sun et al. (2010)

Modifications to GFS code:

(1)The low-level inversion is defined. If shallow convection is active AND κ<0.7, then mixing by shallow convection is limited to be below the inversion. Here, active shallow convection can be interpreted as the presence of decoupling.
(2)Background diffusion is removed below the inversion.

According to the results, a too thick stratocumulus layer appears near the coast. Incorporating "cloud top entrainment" may improve the results, but this requires a more advanced shallow convection scheme.

… (one of the) motivating questions about the Sc-Cu transition is,

the mechanism that finally dissipates the Sc …

… The bigger challenges have been:

(i)to devise parameterizations that reflect out current physical understanding;

(ii) To make these parameterizations work well as a system by properly interacting with each other and reflecting a consistent underlying model of the subgrid scale variability.

---from the CPT proposal

Xiao, Heng, C.-M. Wu and C. R. Mechoso, 2010: Buoyancy reversal, decoupling and the transition from stratocumulus-topped to trade cumulus-topped marine boundary layers. *Climate Dynamics, accepted.*

Sun, Ruiyu, S. Moorthi, H. Xiao and C. R. Mechoso, 2010: Simulation of low clouds in the Southeast Pacific by the NCEP GFS: sensitivity to vertical mixing. *Atmos. Chem. Phys.*, *Sub Judice.*

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